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LACV-30 (LIGHTER AIR CUSHION VEHICLE 30-TON) FUEL LINES

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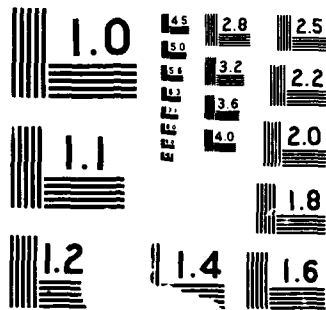
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# technical Report



United States Army  
Belvoir Research, Development & Engineering Center  
Fort Belvoir, Virginia 22060-5606

**REPORT 2455**

**LACV-30  
Fuel Lines**

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## PREFACE

This technical report summarizes the laboratory test analysis and presents photographic results and recommendations for replacing the LACV-30 fuel line system. The original fuel line was a thin-walled aluminum tubing system, prone to corrosion and fuel leakage. Its replacement was expensive and sole sourced. Laboratory testing was performed at the Belvoir Research, Development and Engineering (RD&E) Center during 1984-1987 to identify a suitable solution based on the concept of replacing the aluminum tubing with rubber hose and upgrading the aluminum fittings. Testing and analysis included salt spray, abrasion, and cold temperature resistance; fuel compatibility (JP-4, #2 diesel fuel); and such properties as tensile strength, elongation, volume swell, specific gravity, and peel adhesion.

The LACV's new fuel line system replaces all aluminum tubing and flex joints with standard, low pressure SAE 30 R7 rubber hose and 6061 aluminum interface fittings, connectors, and securing brackets. This new system and its hardware have the following advantages over the original aluminum tubing:

- Increases durability
- Reduces down time and installation time
- Requires no special tools or skills
- Improves safety
- Logistically cost effective and available
- Field repairable
- Reduces number of hose sizes from 13 to 3.

Original laboratory data collections, comparisons, and compilations on tested hoses and fittings may be obtained from Belvoir RD&E Center, Logistics Support Directorate, Marine Division, Marine Development Team.



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## SECTION I. BACKGROUND

The Lighter, Air Cushion Vehicle, 30-ton (LACV-30) is a high-speed aircraft capable of carrying 30 tons of cargo over water, land, ice, and marginal terrain. The primary mission of the LACV-30 for the US Army is the transport of containerized and wheeled cargo from supply ship to shoreside marshalling areas in support of logistics over-the-shore (LOTS) operations. The LACV-30 can also be used in such missions as ice breaking, search and rescue, and other coastal, harbor, and inland waterway roles.

It is the purpose of this report to outline problems with the LACV's existing aluminum fuel line system and to present recommendations for its replacement with rubber hose. The principles of the LACV-30's mission subject the fuel lines to continuous exposure to salt water spray and sand blasting. This necessitates increased resistance to corrosion and erosion for the fuel lines.

The original fuel lines on the LACV-30 consisted of 13 different diameters of rigid 5052-0 aluminum tubing having a wall thickness of 0.049 inch. These tubes were custom fit for each location and application on the LACV-30 (Figure 1), and were held in place using P-clamps with rubber grommets. Expensive sole source procurement of replacement parts increased system cost. To relieve any static electrical charge built up from the flowing fuel, 5052-0 aluminum grounding straps—spaced about 4 feet apart—were clamped directly to the tubing (Figure 2). These clamps were coated with an anticorrosion sealant and fastened with stainless steel nuts, bolts, and washers.

The fuel lines on the LACV-30 are located under the side decks of the craft. While the craft is operating over land, the fuel lines are subjected to continuous sandblasting. While the craft is operating over water, the fuel lines are subjected to continuous salt spray and high vibrational loads transmitted from the craft. After operation of the craft, the fuel lines do not receive a thorough cleaning to remove any salt or sand build-up; thus, the following four corrosion problems affect the LACV-30 fuel lines. The extent of the corrosive damage is depicted in Figure 3.

### PITTING

Localized corrosion in structural alloys. Anodic site (area of corrosion) tends not to shift.

### CREVICE CORROSION

A number of metals, including aluminum, develop a thin oxide film in corrosive environments. This film inhibits the corrosion process by acting as a barrier through which gases and other corrosive substances cannot pass. Eventually, the film breaks down, but can be kept in repair, provided there is a sufficient supply of dissolved oxygen. Metal in a crevice lacking the necessary amount of oxygen will not be able to

replenish its film, and the exposed surface corrodes. In such a reaction, the oxide film nearby becomes the cathode to complete the cell. This type of localized attack is common when the sealant loses its bond with the aluminum, allowing salt water to enter the crevice between the aluminum tube and the sealant.

### **DISSIMILAR METALS**

Two metals in electrical contact with one another create a corrosion cell whereby the metal with the higher EMF series potential oxidizes, cathodically protecting the other. This type of corrosion is apparent at the contact points of the steel nut and bolt with the aluminum clamp and tube.

### **STRESS CORROSION CRACKING**

A metal exposed simultaneously to corrosion and tensile stresses will exhibit stress corrosion cracks.

## SECTION II. ANALYSIS

Two methods of solving the corrosion and subsequent leaking problem were considered. The first and most appealing proposal was to apply a coating to the existing aluminum fuel lines. This was seen as a first choice, since it would require no change to the basic fuel system. The second proposal, in the event the coating solution could not be implemented, was to design a new system using rubber hose instead of the aluminum tubing.

### COATINGS

Six different types of coatings, two different conductive epoxies, and nylon nut, bolt, and washer sets were tried in different combinations in an attempt to prevent the corrosion from attacking the aluminum tubing. Samples of the coated tubes were subjected to 360 hours in salt spray cabinets, sand blasting tests, and adhesion tests. Samples of these coated lines were also bolted to test racks and attached under the side decks of operational craft at Fort Story, VA. Figure 4 shows tubing samples before being placed in the salt spray for 360 hours, and Figure 5 shows a sample rack before being attached to a LACV-30 at Fort Story.

Unfortunately, this solution was unusable since none of the coatings which were tried passed the salt spray or the adhesion test. Figures 6A through 6E show various samples after the salt spray chamber. All samples showed signs of corrosion. Figures 7A and 7B show two samples of an uncoated line with a conductive epoxy between the tube and grounding strap. The two materials corroded severely due to the use of copper and carbon as the conductive filler for the epoxy.

### RUBBER HOSE

The second approach to solving the fuel line corrosion problem was to replace all of the aluminum tubing with an elastomeric hose. This required the selection of a hose which would resist sand abrasion and salt water on the exterior, and JP-4 and #2 diesel fuel on the interior. It also required the redesign of all support brackets and fittings. Since a system redesign was already necessary, it was decided to improve the logistical supportability of the LACV-30 by using only three sizes of fuel lines: 1½ inch, ¾ inch, and ⅜ inch.

Eleven different types of rubber hoses were tested in the laboratory to the following specific test requirements:

**Initial**

Tensile Strength - psi	ASTM D-412
Elongation - %	ASTM D-412
Modulus at 200% Elongation psi	ASTM D-412
Shore A Hardness	ASTM D-2240

**After Fuel Aging  
(48 Hrs in Reference Fuel B, and Diesel Fuel)**

Tensile Strength Retained - %	ASTM D-471
Elongation Retained - %	ASTM D-471
Modulus Retained - %	ASTM D-471
Hardness Change - points	ASTM D-2240

**Fuel Extraction in Reference Fuel B of ASTM D-471**

Unwashed (Existent) Gum	ASTM D-381
Washed Gum	ASTM D-381

**Sand blast at 30, 45, and 90 psi with different angles (normal and tangential)**

In addition, since a new type of fuel line is to be used, new fittings must be used. It was decided that 6061 aluminum would be used rather than 5052-0 aluminum, as in the original system, in light of its greater resistance to corrosion. These fittings will be anodized to further increase the corrosion resistance.

### SECTION III. RESULTS AND CONCLUSIONS

In accordance with laboratory and field testing previously described, the Chemistry Research Group in the Materials, Fuels and Lubricants Laboratory recommends the use of rubber fuel line hose conforming to SAE J30, class 30R7 for all sizes. For the aluminum hose couplings to be used in the retrofitting of the LACV-30, the Group recommends the following minimum requirements:

ALLOY: A1 6061-T6

ANODIC COATING: MIL-A-8625, Type II, Class 1, 0.0007 inch minimum thickness

In order to solve the corrosion problem of the fuel lines on the LACV-30, a system redesign conforming to the above requirements was necessary. The complete redesign is detailed in TDP TL/TA 13227E66450, and has the following advantages over the current system:

- Increased durability.
- Reduced down and installation times,
- Improved safety,
- Cost effectiveness,
- Field repairable, and
- No special tools or skills are required.



Figure 1. Custom-Fitted Fuel Lines

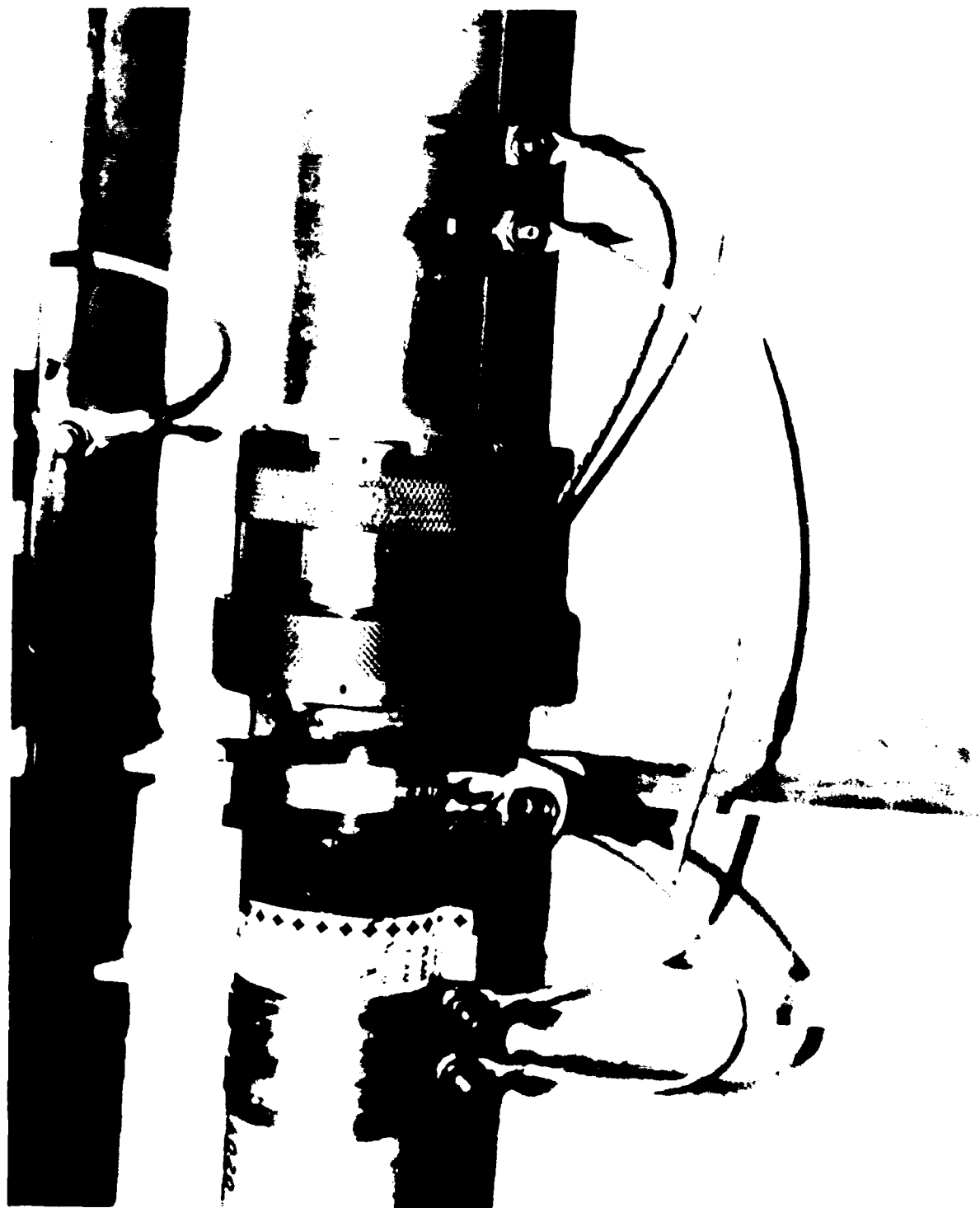


Figure 2. Aluminum Ground Straps, 5052-0 Aluminum



Figure 3. Corrosive Damage

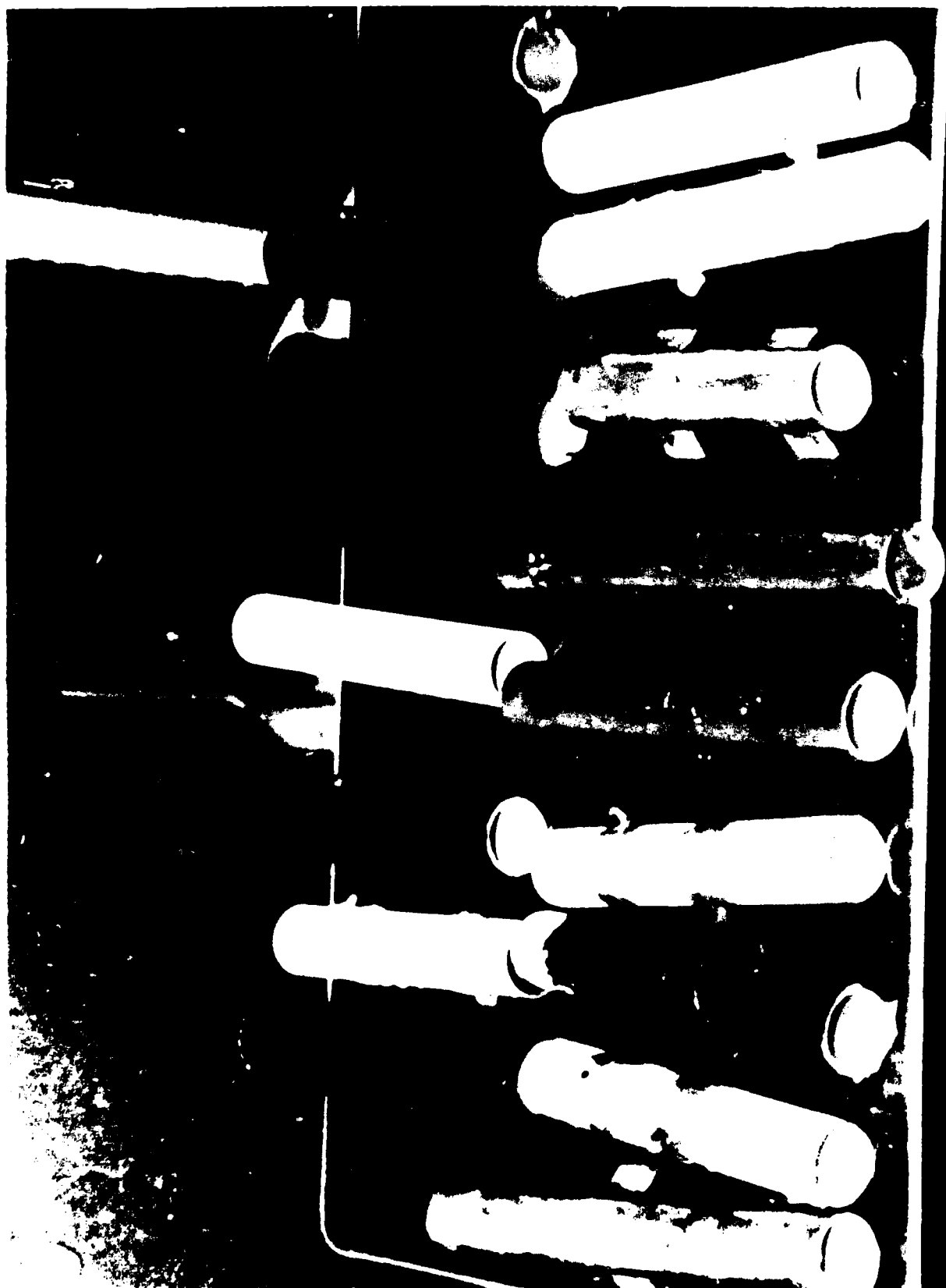


Figure 4. Test Samples for Lab Testing in Salt Fog Atmosphere



Figure 5. Test Rack of Candidate Coatings for Installation on Craft

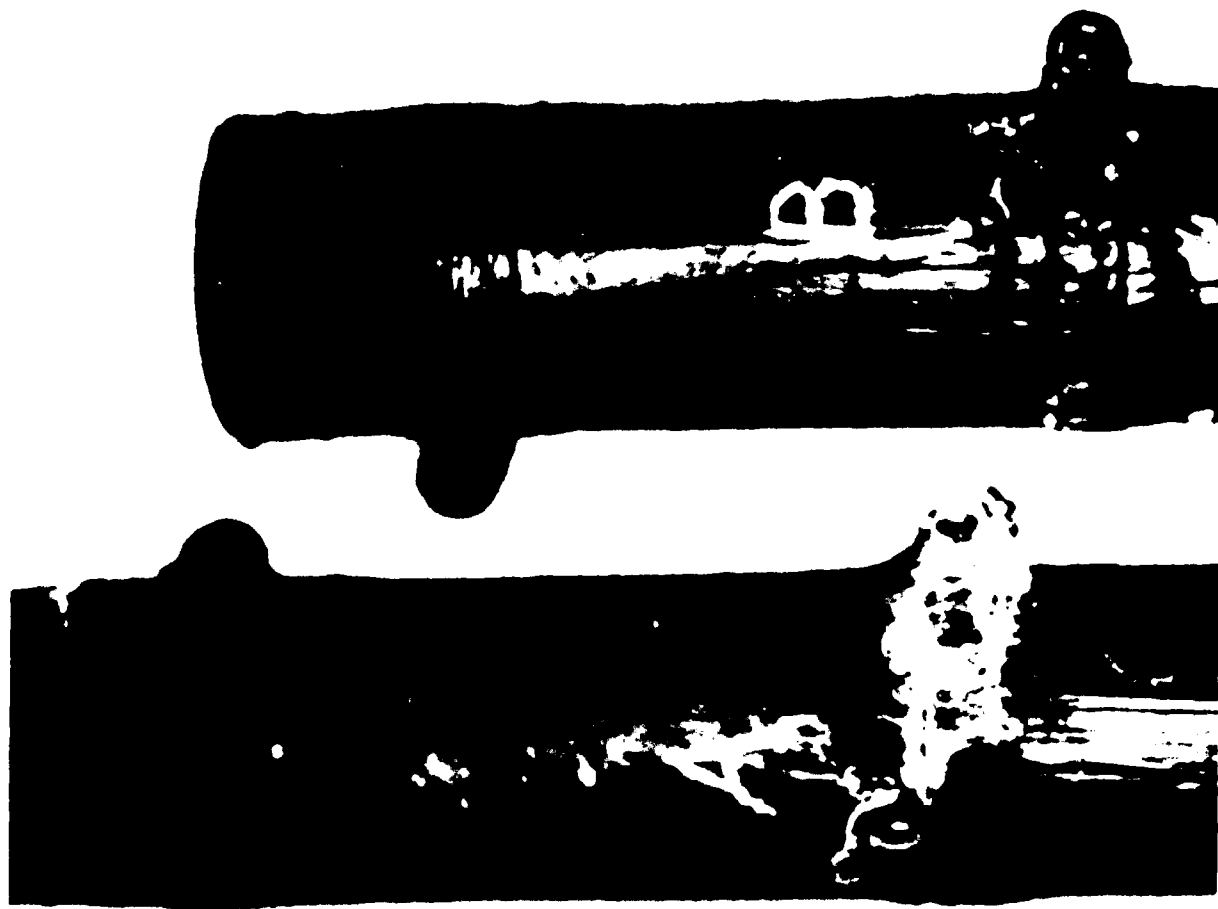


Figure 6A. LACV-30 15-Day Exposure, Salt Fog Cabinet

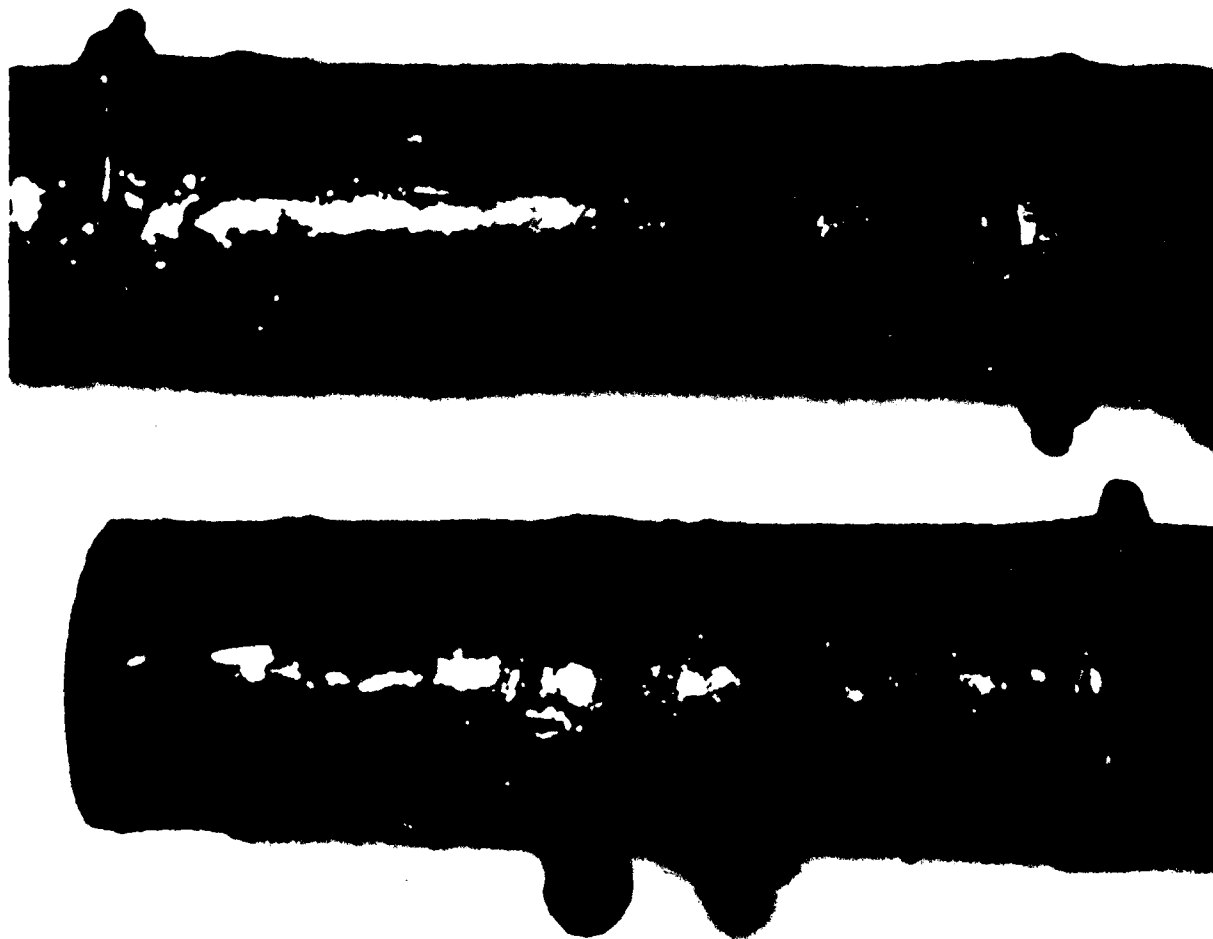


Figure 6B. LACV-30 15-Day Exposure, Salt Fog Cabinet



Figure 6C. LACV-30 15-Day Exposure, Salt Fog Cabinet

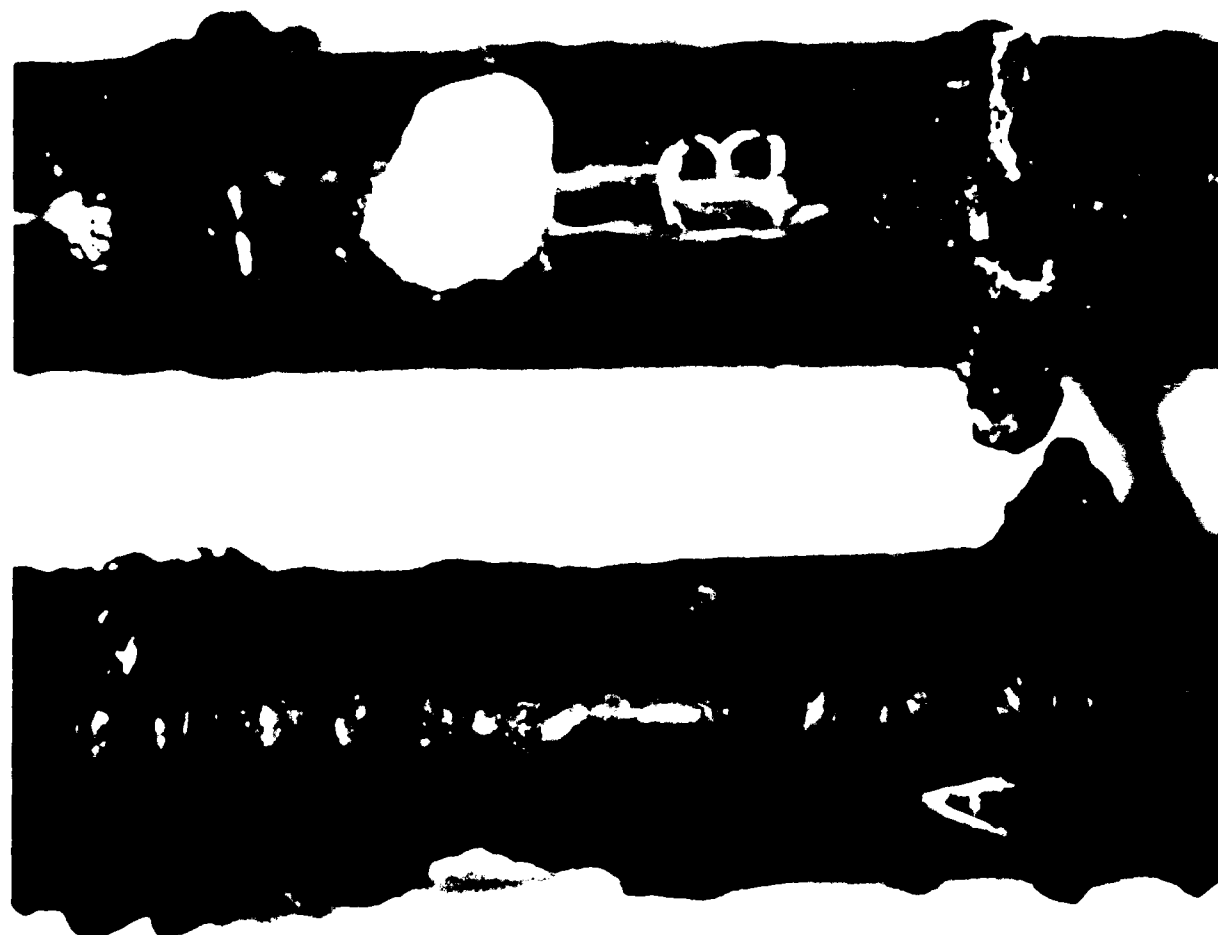
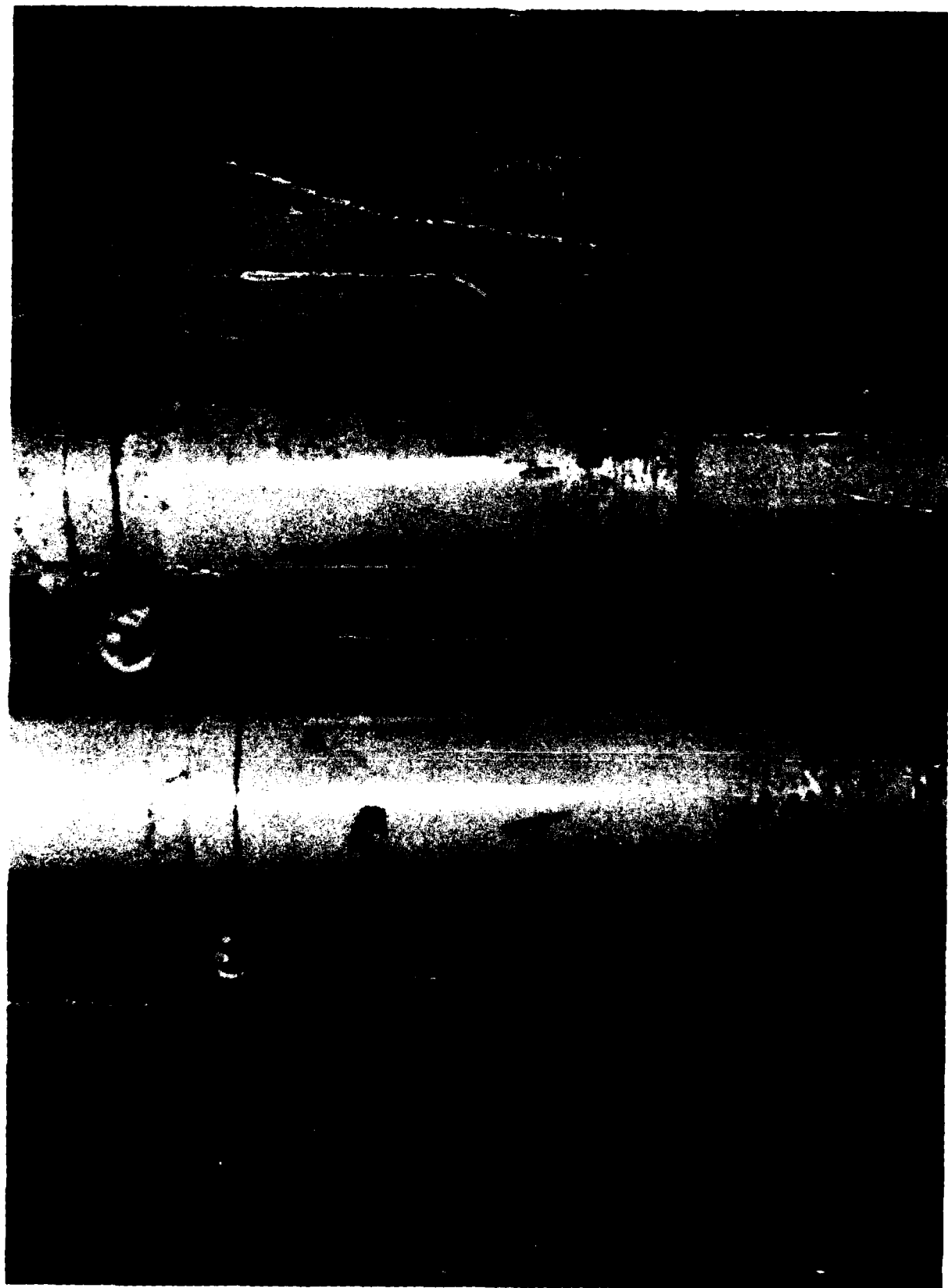


Figure 6D. LACV-30 15-Day Exposure, Salt Fog Cabinet



**Figure 6E. LACV-30 15-Day Exposure, Salt Fog Cabinet**



**Figure 7A. Uncoated Line with Conductive Epoxy**

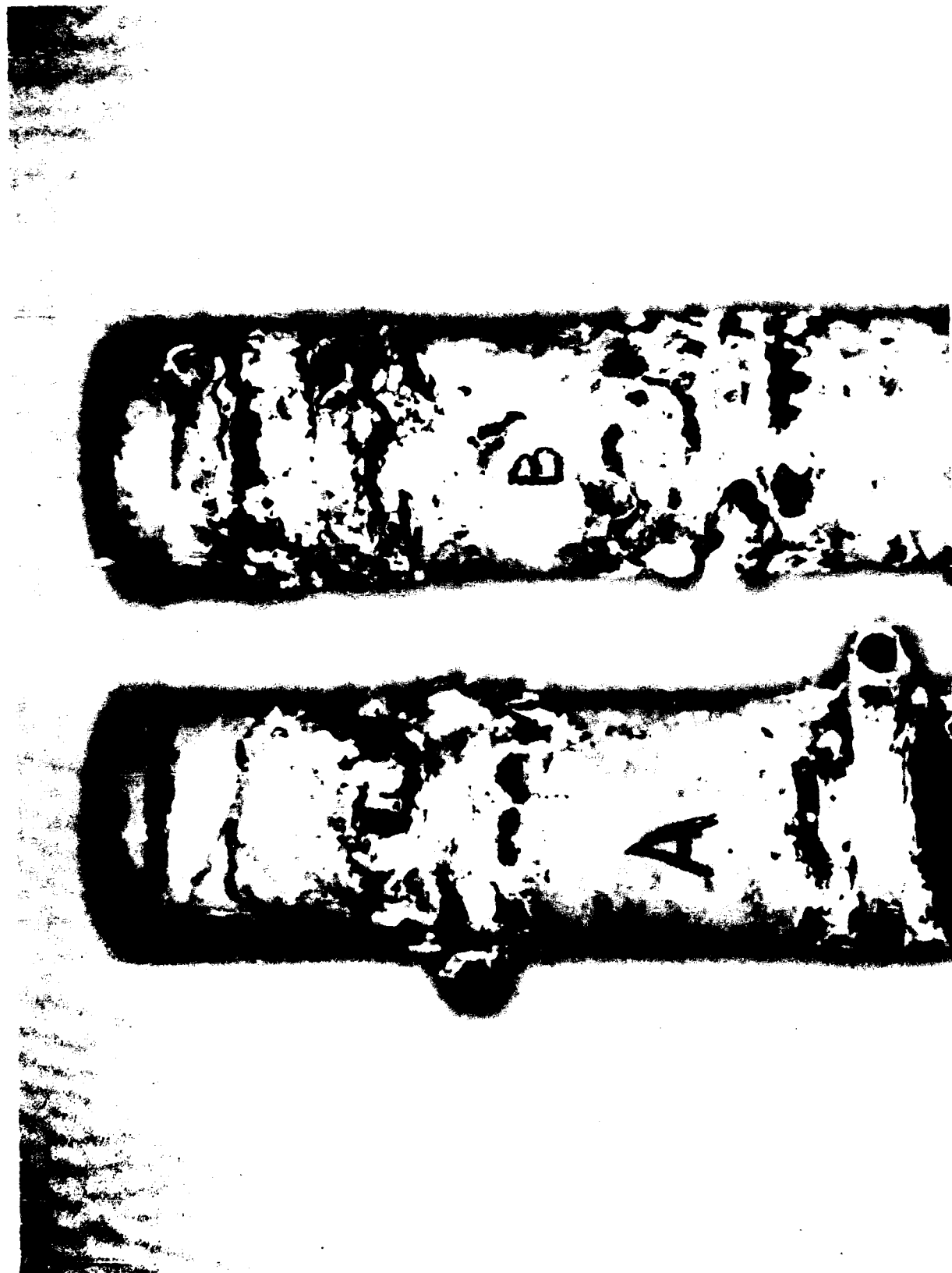


Figure 7B. Uncoated Line with Conductive Epoxy

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